2009 JPL SURP Strategic Topic Areas

Topic Area:	8. Fractionated, distributed, reconfigurable, repairable, reusable missions
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Summary:
Distributing functionality among and within space systems will confer benefits in the form of improved reliability, robustness, efficiency, versatility, and productivity.

Description:
Individual spacecraft are typically designed with "monolithic" hardware and software architectures; that is, modular concepts do not inform individual system architectures. Moreover, individual systems are often designed to satisfy narrow, mission-specific requirements without consideration of broader, multi-mission operating concepts or longer term science objectives. While such design approaches may help mitigate known mission-specific risks, they do so at a cost: such systems are less robust in the face of unanticipated off-nominal events, less capable of adapting to changes in mission objectives, less responsive to changing requirements across programs, and far less versatile in accomplishing a broader range of objectives. Moreover, these architectures do not lend themselves to re-use, and can hinder distribution of the engineering effort across disparate organizations.

To address these limitations, there is interest in developing systems and software engineering expertise in the design of new classes of spacecraft architectures (hardware, avionics and software) that exhibit the following features:

- <u>Fractionated and Distributed:</u> Decoupling and distribution of functions across system elements not only enables greater flexibility and robustness in individual missions, it allows multiple missions to share resources and mitigate risk. Examples include "plug & play" multi-mission architectures supporting stand alone elements that provide their own computation, power, communication, etc., or access their needed resources from other elements (e.g., "beaming" power between spacecraft in a constellation).

- <u>Reconfigurable:</u> Improved versatility can be achieved by developing spacecraft capable of reconfiguring themselves in order to achieve unanticipated mission objectives. Designing reconfigurable hardware and software architectures will additionally enable systems to overcome unanticipated failure situations, and thus more robustly achieve their original objectives.

- <u>Repairable:</u> Because existing "one-off" missions cannot access capabilities from other spacecraft, fault protection functionality is typically hard-wired into individual systems. While missions such as DARPA's Orbital Express have demonstrated on-orbit repair capabilities, extrapolating these initial concepts to support more sophisticated notions of in-situ repair – either on-orbit or on planetary surfaces – will require novel spacecraft architectures. Repair operations may be performed autonomously, or may employ humans-in-the-loop (e.g., an astronaut swapping out a robot's failed instruments by hand).

- <u>Reusable:</u> The above features (fractionation, distribution, reconfigurability, and repairability) will also prolong the useful lifetimes of space systems. A repairable system can get a second chance at a useful life, even after experiencing a failure that would cripple or end a mission today; a spacecraft that has been architected for reconfigurability might be able to accomplish new science and exploration objectives, even when its original configuration is no longer useful.

JPL is seeking proposals to tackle this Challenge from a multi-disciplinary, "systems" perspective. There is interest in exploring the benefits of such systems for either multi-spacecraft systems-of-systems, or modular single-spacecraft systems. Submissions in response to this call might propose the following types of deliverables:

- Specifications of systems engineering methodologies
- Analysis and Design tools for use across the engineering lifecycle
- Architecture specifications (including key patterns)
- Approaches and algorithms for system-level control and coordination
- Proof of concept system implementations and demonstrations (in simulation and/or hardware testbeds)
- Scenarios that quantify the benefit of architectures that move beyond single-element mission concepts with self-contained resource envelopes, enabling reuse for significantly different missions.